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GB 1233546
GB 1113964
GB 1078459
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(54) Magnetic coil apparatus for metal working and welding

(57) A magnetic coil assembly B comprises an insulating body (1) (9) and a conductor (2) (10). The assembly B is such that it can be located around a section of a component to be treated without having to be passed over the adjacent sections of the component. This is achieved by the body (1) being formed of hinged or separable portions, A and C, with the conductor (2), (10) being permanently embedded in the body (1) (9) or being inserted into a receiving cavity provided in the body after the body has been located around the component. If the conductor is permanently embedded in the body (1) electrical connectors ensure a good electrical circuit. The conductor may be in solid or liquid form. In an alternative embodiment the conductor may be wrapped onto the insulating body which is then deformed around the component.

FIG.2

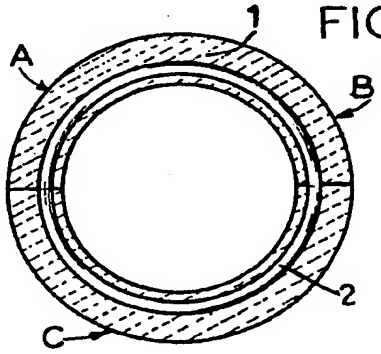
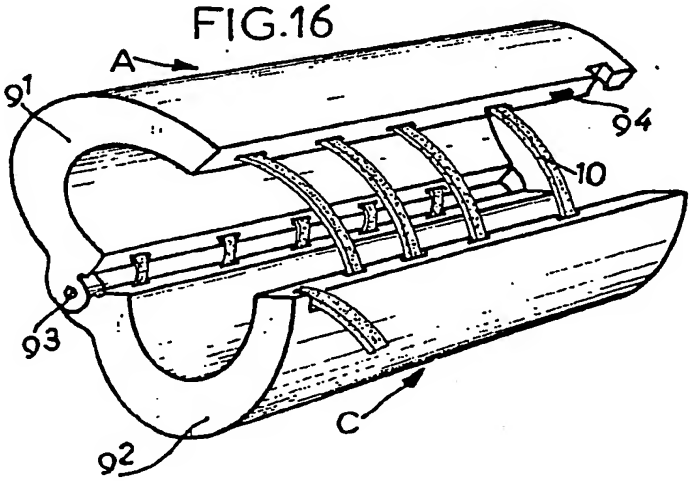


FIG.16



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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FIG.1

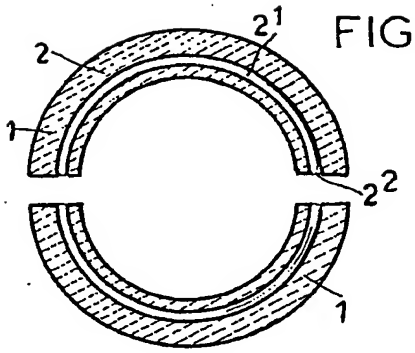


FIG.2

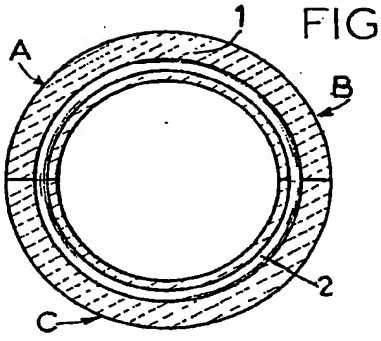


FIG.3

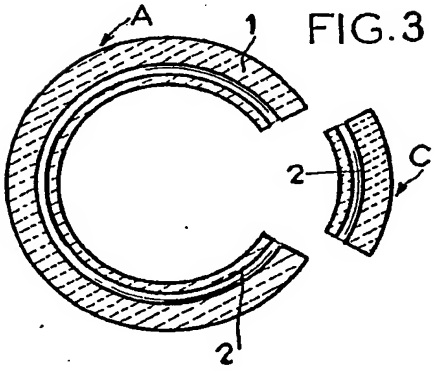


FIG.4

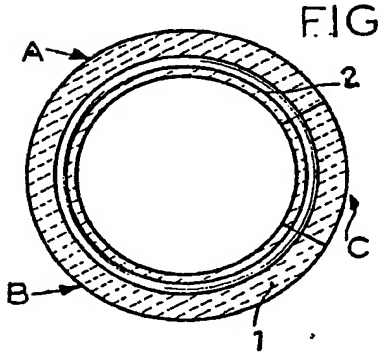


FIG.5

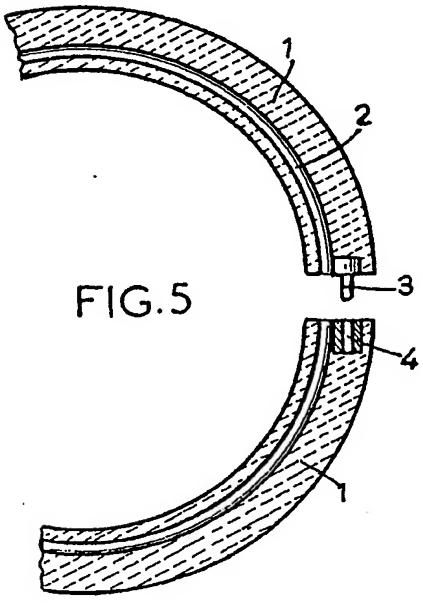
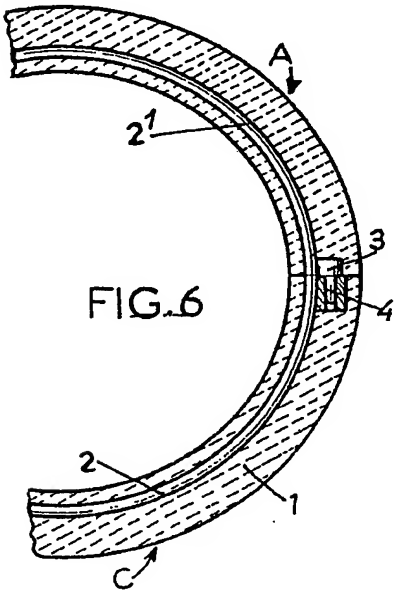


FIG.6



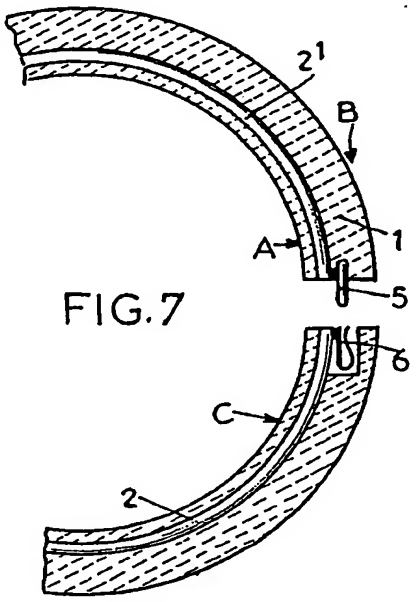


FIG.7

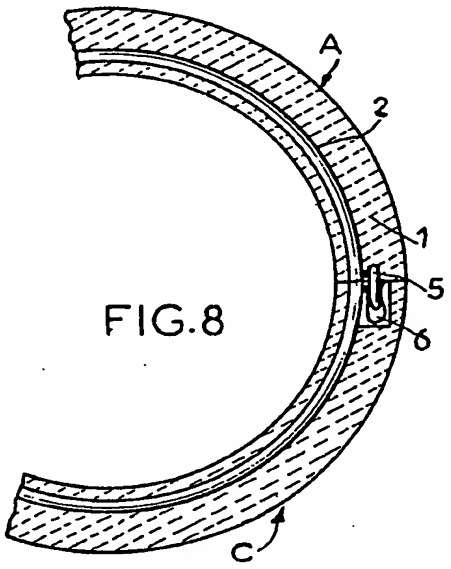


FIG.8

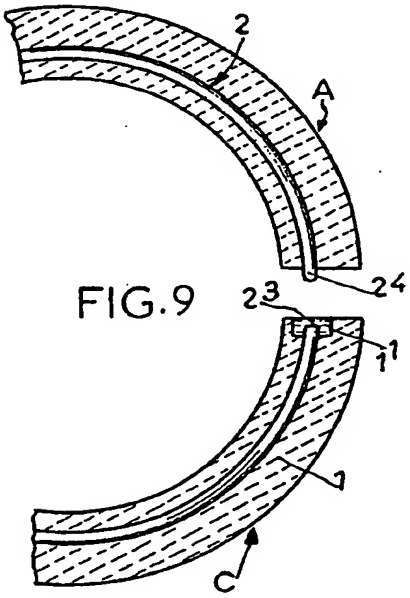


FIG.9

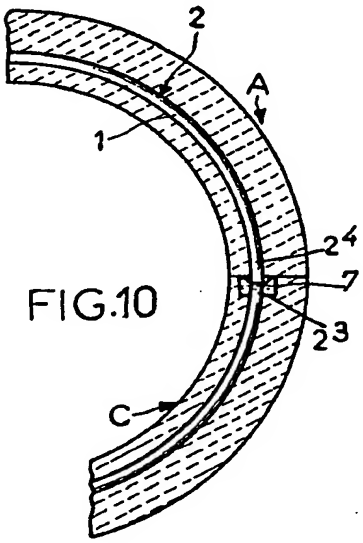


FIG.10

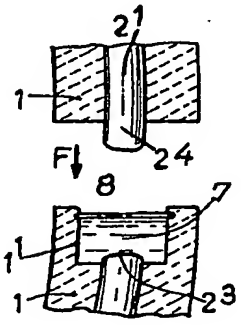


FIG.11

FIG.13

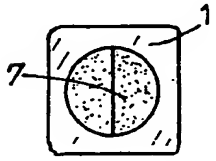


FIG.12

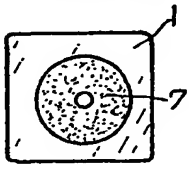
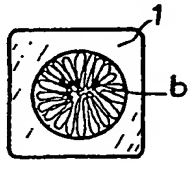


FIG.14



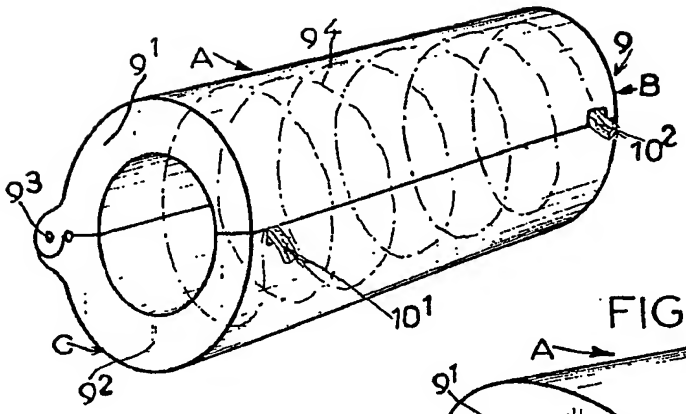


FIG.15

FIG.16

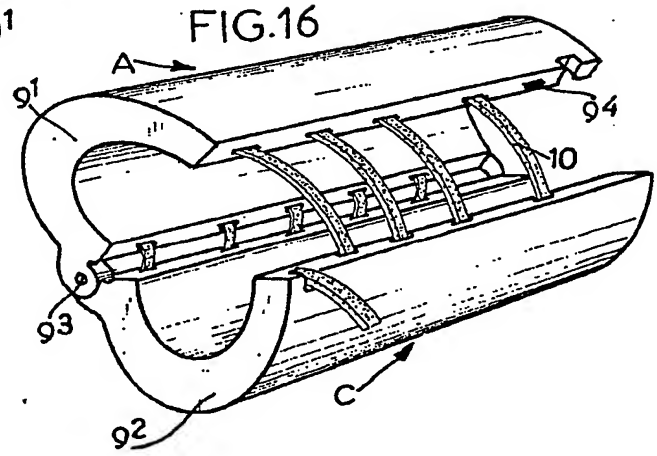


FIG.17

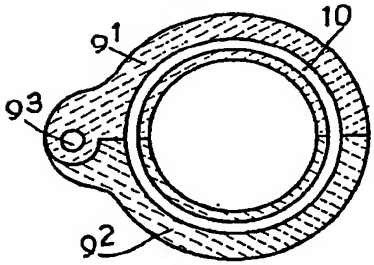


FIG.18

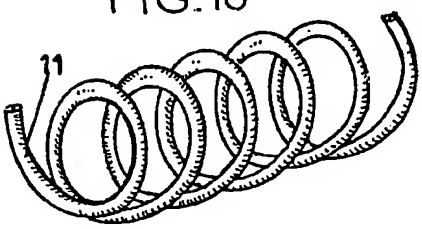


FIG.19

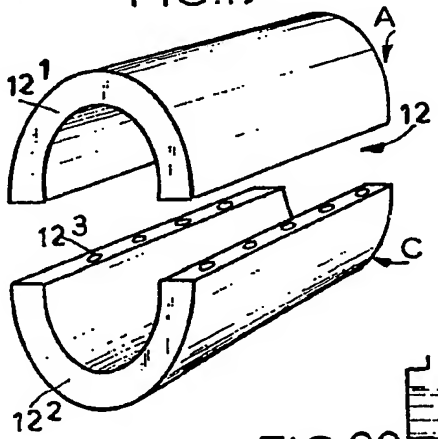
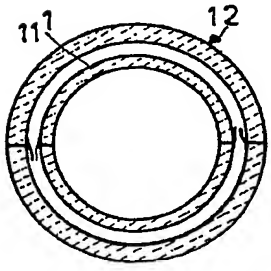


FIG.21



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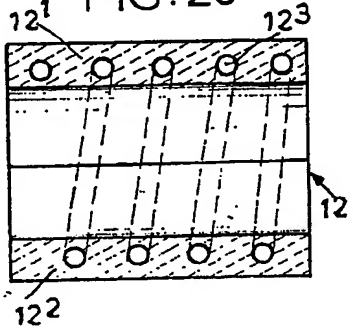
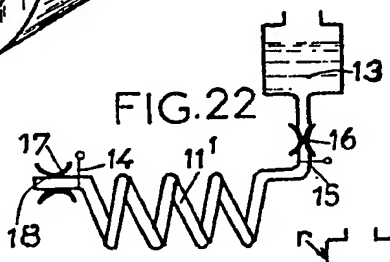


FIG.22



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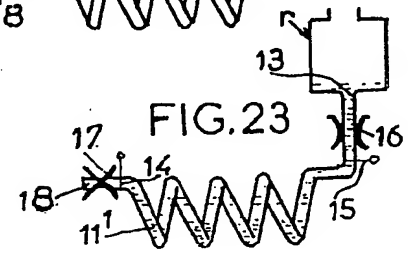


FIG.24

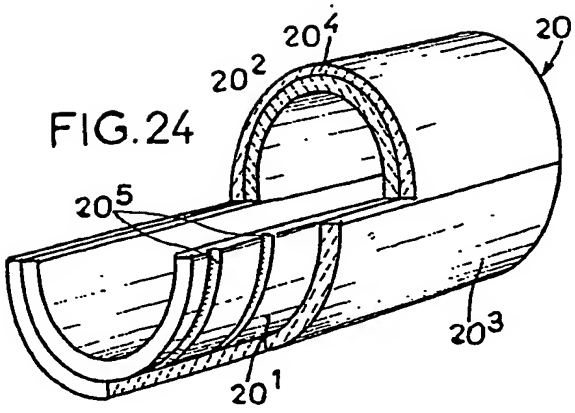


FIG.25

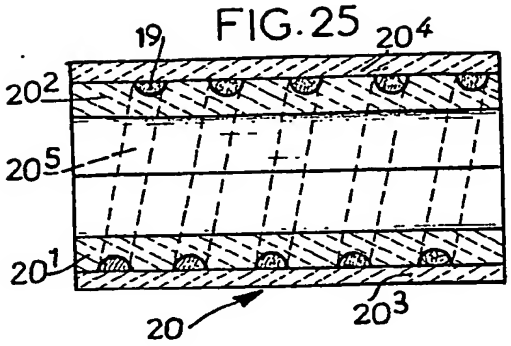


FIG.26

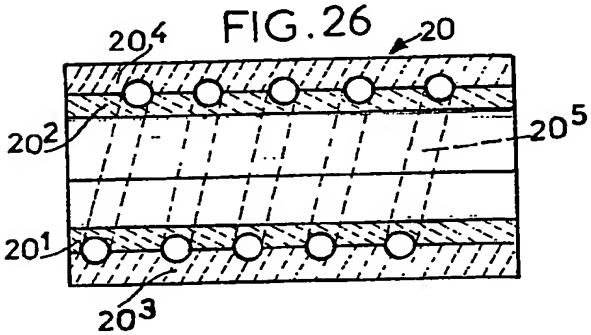


FIG.27

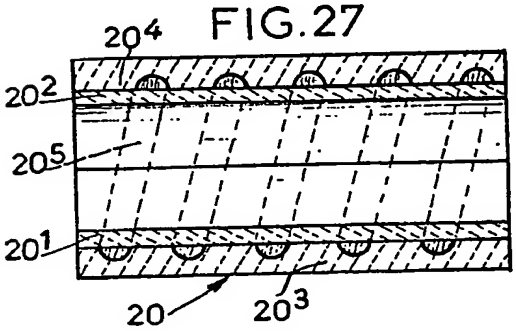


FIG.28

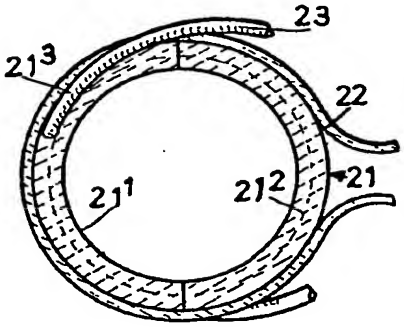


FIG.29

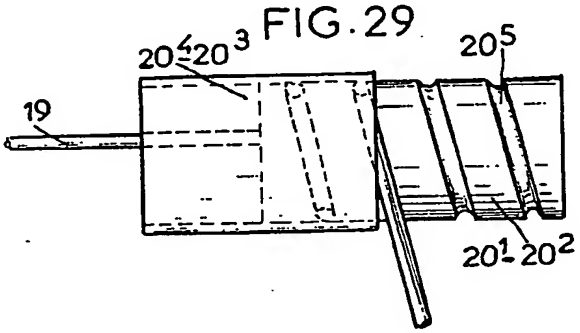


FIG.30

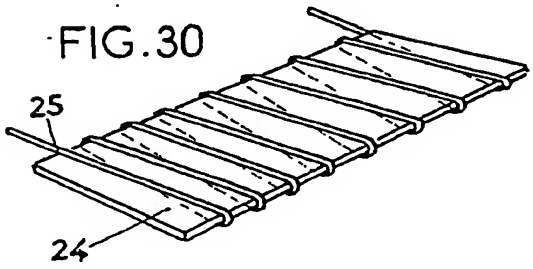
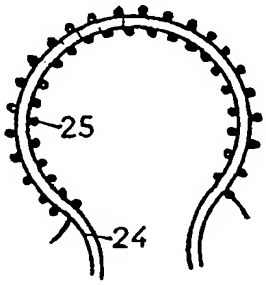


FIG.31



SPECIFICATION

Magnetic coil

The invention relates to a coil designed for generalised use in the magnetic forming method, and the methods and means for manufacturing this coil.

The subject matter of the invention relates in particular to the technical fields of devices and methods for joining, assembling or otherwise connecting various components or elements, as well as to the technical field of electricity.

Methods for electromagnetic forming and welding are known in which electrical energy previously accumulated in capacitors is released at a high intensity into a coil suitably disposed with respect to the components to be treated. These methods are better known as magnetic welding or magnetic forming. In brief the principle of these methods is to pass induced currents through the components to be treated made of metal which conducts electricity under the action of the variation of the magnetic field of the coil. The combination of the magnetic field and induced currents arising from the laws of Laplace and Foucault, produces a force capable of deforming, assembling or treating components instantaneously and without contact.

Certain specific applications using the magnetic welding or magnetic forming method have been proposed.

However there is a major drawback in the case of a large number of applications which would be very advantageous. The magnetic forming coil made from a conductive element located in an insulating body or envelope is generally placed around the components to be treated. When the operation is finished, the coil must be removed by causing it to slide along the component up to its end. This cannot however be carried out in the case of closed systems with very long or long components or when the coils may not be engaged at the ends.

In accordance with the invention and in order to overcome these difficulties and in order to generalise as far as possible the applications of the magnetic forming method, a magnetic forming coil has been designed which is characterised in that its main components, i.e. conductor and body, are provided in one or several portions which may be opened and/or deformed such that they may be fitted about or withdrawn from the components to be subjected to magnetic forming in many cases (for example closed systems, long components, ends which may not be engaged by the coils etc) in which the coils may not be positioned normally.

The invention also relates to methods and means for producing this coil in various embodiments.

According to a first embodiment, the helical conductor forming a solenoid and the corresponding body having a cylindrical or other shape adapted to the component to be formed are produced in at least two portions having their surfaces of connection and assembly in diametral or radial planes.

According to a further embodiment, only the body is constructed of several elements which may be opened or fixed together in a detachable manner, which elements are arranged internally or externally to receive in a detachable manner the conductor element.

According to a further embodiment, the conductor element is connected to a body made of a material or substance which may be elastically deformed into various shapes either mechanically or manually.

These and other characteristic features will become evident from the remainder of the description.

The invention is described in a non-limiting manner in the attached drawings, in which:

Figure 1 is a diagrammatic front view in cross-section showing a circular magnetic forming coil divided in a diametral plane;

Figure 2 is a similar view to Fig. 1, after the divided portions of the coil have been joined;

Figure 3 is a diagrammatic front view in cross-section showing a circular magnetic forming coil divided in radial planes;

Figure 4 is a similar view to Fig. 3 after the divided portions of the coil have been joined;

Figures 5, 6, 7, 8, 9 and 10 are partial front and cross-sectional views of a circular magnetic forming coil whose body and conductor element having the shape of a solenoid are cut diametrally; more particularly:

Figures 5, 6, 7, 8 show respectively by way of example mechanical means for the temporary connection of the turns of the solenoid; Figs. 5 and 7 showing the coil before connection of the turns, and Figs. 6 and 8 after the connection of the turns.

Figures 9 and 10 show an example of temporary connection of the turns by means of a fluid which conducts electricity; Fig. 9 showing the coil before connection of the turns and Fig. 10 showing the coil after connection of the turns;

Figure 11 is on an enlarged scale and is a partial cross-section in accordance with the embodiment of Figs. 9 and 10 before connection of the turns;

Figure 12 is a plan view along the arrow F of Fig. 11;

Figures 13 and 14 are similar views to Fig. 12 showing further embodiments;

Figure 15 is a perspective view of a magnetic forming coil of the invention whose body is constructed of two half-shells which may be opened, constituting a gripper, and arranged internally so as to enable, by various means, the simple introduction and removal of a solid state conductor element;

Figure 16 is a view corresponding to Fig. 15 showing the opening of the gripper and consequently the removal of the conductor element;

Figure 17 is a cross-section through a turn in accordance with the embodiment of Fig. 15;

Figure 18 is a perspective view of a helical coil;

Figure 19 is a perspective view of two shell elements designed to form the body and the coil and obtained from the coil of Fig. 18 previously divided into two, in order to constitute in this way a helical cavity designed to contain a fluid conductor element;

Figure 20 is a longitudinal section through the coil corresponding to the embodiment of Fig. 19;

Figure 21 is a cross-section along the line 21–21 of Fig. 20;

Figures 22 and 23 are diagrammatic views showing the filling and inversion of the helical cavities forming turns, relating to the embodiment of Figs. 19 and 21;

Figure 24 is a perspective view of a coil which may be dismounted in accordance with the invention obtained substantially from at least two internal shell elements and at least two external shell elements, for the mounting and removal of a solid state conductor element;

Figures 25, 26, 27 are longitudinal sections showing various embodiments deriving directly from the embodiment of Fig. 24;

Figure 28 is a cross-section corresponding substantially to the embodiment of Fig. 24 in which the external shell is replaced by a sheet of insulating material;

Figure 29 shows a method of assembling the coil in accordance with the embodiment of Figs. 24, 25, 26, 27 and 28 in particular;

Figure 30 is a diagrammatic perspective view showing a further embodiment of the coil constructed from an elastically deformable insulating material;

Figure 31 shows the deformation of the coil corresponding to the embodiment of Fig. 30.

The invention is now described in detail in a non-limiting manner with reference to the drawings.

Figs. 1 to 10 in particular show a magnetic forming coil designated overall by *B*, and having a cylindrical or other shape adapted to the geometry of the component to be treated. In a known manner, the coil comprises an insulating body 1 having a high electrical resistivity, and is provided internally with a helical conductor 2 constituting a solenoid of copper or of any other material which conducts electricity.

In accordance with the invention, the solenoid 2 and the body 1 are constructed of at least two portions A and C whose surfaces of connection and assembly are in diametral planes (Figs. 1 and 2) or in radial planes (Figs. 3 and 4). It is evident that according to requirements it is possible to construct the helical conductor 2 and the body 1 in any number of segments whose planes of connection and assembly pass through the axis of the magnetic forming coil. The connection ends 2^2 of each turn 2^1 of the solenoid are then provided with connection means ensuring electrical conduction, after connection of the portions A and C of the coil. Some non-limiting examples of electrical connection are shown in Figs. 5 to 14.

In Figs. 5 and 6, the electrical connection of each turn element 2^1 for reconstituting the complete solenoid is carried out by means of male and female plugs 3 and 4 which may be fastened together and are known as "banana plugs" having one or several radial contacts. In Figs. 7 and 8 a complementary system of blades 5 and clamps 6 or any other equivalent means acting by expansion or clamping is used.

It is also possible to ensure the electrical connection of each turn element 2^1 by immersing one of its ends 2^3 in a fluid 7 which is a good conductor of electricity (mercury, brine etc.) connected electrically to the corresponding end 2^4 of the following turn element (Figs. 9, 10 and 11)). The fluid 7 is contained in a cavity 1^1 of the body 1 and may be sealed in a leak-tight manner by means of a diaphragm 8 (Figs. 12 and 13) of a material which may be readily deformed during connection of each turn of the solenoid 2 (Fig. 11). If the conducting fluid 7 has a sufficient surface tension an assembly of brushes b acting as an obstacle to the fluid is used as a means for sealing the fluid 7, which brushes are designed to enable passage of the end of the turn which is caused to penetrate therein (Fig. 14).

According to a further variant of the embodiment of the magnetic forming coil in accordance with the invention, the body is constructed of several elements which may be opened or assembled together in a detachable manner, and are arranged internally and/or externally to receive the conductor element temporarily.

In general the various elements constituting the body have a helical cavity or a like hollow recess shaped suitably for the coil provided for the operation; the said recess is provided with the conductor element which may belong to the four states of matter: solid, liquid, gaseous, plasma. In the following description, the magnetic forming coils described have their conductor element in the solid or liquid state.

Figs. 15, 16 and 17 show a body 9 of cylindrical shape which is separated diametrally to constitute two shells 9^1 and 9^2 which, in accordance with the drawings, are arranged at 9^3 so as to be articulated with respect to one another by any known and suitable

means and constitute a gripper which may be opened (Figs. 15a and 16). In accordance with the invention a helical cavity 9^4 (dot-dash lines in Fig. 15) designed to enable the housing of the conductor element is provided in each shell 9^1 and 9^2.

In the case of a solid conductor element, this is chosen to be flexible so that it may be readily introduced and withdrawn from the cavity 9^4 in particular during opening of the body 9 (Fig. 16). For example copper wire 10 which has been carefully annealed is inserted into the helical cavity 9^4 and is housed there as a result of its flexibility until its two ends 10^1 and 10^2 emerge from the cavity 9^4 (Fig. 16) so as to be gripped and connected to a pulse generator. The cavity 9^4 may also be provided, again by insertion, with a flexible braid of the conductor metal.

The conductor wire 10 may also be introduced (and vice versa) by mechanical means. For example the end of the wire 10 is provided with a piston or the like such that an introduction of compressed air ensures the winding of the wire 10 in the cavity 9^4 until it emerges in order to be connected to the pulse generator. A piston moved by the pressure of a fluid may also entrain any connction in the cavity 9^4 in order then to draw out the flexible conductor 10.

Use may also be made of the forces resulting from the electromagnetic field required for the metal constituting the conductor wire to be suitably wound in the cavity 9^4.

In the embodiment of Figs. 18 to 24, a tubular helical coil 11 (Fig. 18) is provided and is cut in one or more diametral planes. An insulating material is then caused to flow around the cut portions of the coil 11 in order to constitute two or more shell elements 12^1 and 12^2 (Fig. 19) designed for the formation of the open body of the coil (Fig. 20). When the shell elements 12^1 and 12^2 are assembled (Fig. 21) hollow turn elements 11^1 are provided and are connected together in a leak-tight manner by any known and suitable means such as those currently used in hydraulics.

The body 12 is therefore provided with a leak-tight helical cavity 12^3 which ascts as container for a fluid which is a good conductor of electricity (mercury, brine etc.).

In the case of the use of a fluid conductor, it is indispensable to prevent the formation of air bubbles which may lead to the formation of an arc and the impairment of the characteristics of electrical conductivity of the fluid and thus substantially reduces the efficiency of the very intense current required for obtaining the magnetic pulse. Figs. 22 and 23 show diagrammatically an example of the filling of the turns 11^1 constituting a solenoid whose elements are connected at 14 and 15 to taps 16 and 17.

After closure of the body 12 (connection of the shells 12^1 and 12^2) the air contained in the turns 11^1 of the coil (Fig. 22) is suctioned through an orifice 18, the tap 16 being closed and the tap 17 open. When there is a sufficient vacuum to attract the fluid 13, the tap 17 is closed and the tap 16 opened. The fluid 13 contained in a tank is therefore suctioned into the hollow spires 11^1 and comes into contact with the connection bar 14. The tap 16 is then closed and the coil may then be connected to the pulse generator in particular by means of connection terminals 14 and 15.

After the required electrical pulse has been supplied to the coil, the pressure is increased through the orifice 18 and the taps 16 and 17 are opened. The fluid 13 is again directed into the tank r. When the fluid 13 has passed through the tap 16, the latter may be closed and the shells 12^1 and 12^2 of the body may be separated.

In the embodiment of Figs. 24 to 27, the magnetic forming coil which may be dismounted in accordance with the invention is obtained from a solid conductor element 19 (copper wire or other conducting material), and a dismountable insulating body 20 composed of at least two internal shell elements 20^1 and 20^2 and at least two external shell elements 20^3 and 20^4 (Fig. 24). The wire 19 is mounted in the form of a solenoid between each of the shell elements 20^1, 20^2, 20^3, 20^4 so that it may be readily dismounted.

For this purpose, a helical groove 20^5 is provided either of the external periphery of the internal shells 20^1, 20^2 (Fig. 25), or on the internal periphery of the external shells 20^3, 20^4 (Fig. 27), or even distributed jointly on the internal shells 20^1, 20^2 and the external shells 20^3, 20^4 (Fig. 26). The helical groove 20^5 has a square, semi-circular or other section with the single condition that its width substantially corresponds to the sectional profile of the solid conductor element which is to be disposed therein.

The external shell elements 20^3 and 20^4 must be maintained in a closed position by a device designed to resist the forces which tend to open them during the magnetic forming operation itself. For this purpose it is possible to use, for example, a machanical device whether combined or not with a hydraulic, pneumatic electrical system etc.

Radial play is provided between the internal shells 20^1, 20^2 and external shells 20^3, 20^4 in order to correctly pre-stress the turns of the conductor element 19.

The assembly of the coil about the components to be treated is as follows. After assembly of the internal shells 20^1 and 20^2 and the closure of the external shell 20^3, 20^4, the conductor element 19 is partially positioned in the helical groove 20^5 and the assembly is introduced into the external shell 20^3, 20^4 by a combined axial thrust and screwing move-

ment (Fig. 29).

The design of Figs. 24 to 27 shows an insulating shell 21 which is cut diametrally to form two symmetrical portions 21^1 and 21^2. A helical groove 21^3 is then constructed in the external periphery of the shell 21. A sheet 22 of insulating material may be wound about the internal shell 21 in order to constitute in this way, in combination, a helical cavity designed to receive the solid conductor element 23.

Lastly, it is provided to construct a magnetic forming coil which may not be opened but which is deformable in order to temporarily lock the components to be treated (Fig. 31).

In this case, the body 24 is made of an insulating matter or material which may be elastically deformed, in which the conductor element may be a copper wire 25 mounted helically in or on the body 24 (Fig. 30).

It is obvious that the magnetic forming coils of the invention may be constructed in all sizes.

Moreover the body may have different shapes and sections, whilst being arranged and shaped to be readily opened in at least two portions in the form of grippers or shells which may be readily mounted or dismounted, whether in combination or not with the conductor element. In the same way the cooling of the coil may possibly be carried out, in the case of intensive use, by any known device in which a fluid circulates in the conductor which is then tubular or parallel to this latter.

From the advantages shown in the description the generalization of the magnetic forming method to many Applications (closed systems, long components, ends which may be engaged by the coils) is emphasised. This may cover for example the assembly of pipelines, bicycle frames, central heating radiators and their tubing etc.

The invention is not limited in any way to its methods of application, or to those embodiments of its various portions which have been shown in detail. The invention in effect covers all the variants of these.

CLAIMS

1. A magnetic coil assembly for use in magnetic welding and magnetic forming applications comprising an insulating body having a plurality of sections capable of being interconnected around a component to be treated and having a cavity passing through the body for receiving a conductor which constitutes the coil.

2. A magnetic coil assembly as claimed in Claim 1, in which a respective conductor segment is secured in each body section and the ends of each conductor segment are provided with connector means for providing electrical connection between sequential conductor segments when the body sections are interconnected.

3. A magnetic coil assembly as claimed in Claim 1, wherein interconnections between the body sections are fluid tight and in which a fluid conductor is received.

4. A coil designed for the general use of the magnetic forming method, and the methods and means for producing this coil comprising a helically wound conductor element mounted on or in a body having a high electrical resistivity, the said coil being characterised in that its main components, i.e. the conductor and the body, are arranged in one or more portions such that they may be opened and/or deformed, in order to be fitted around or withdrawn from the components to be magnetically formed, in many cases (closed systems, long components, ends which may not engaged by the coils etc.) in which the coils may not be normally positioned.

5. A coil as claimed in claim 4, characterised in that the helical conductor (2) forming a solenoid and the corresponding body (1) having a cylindrical or other shape adapted to the component to be formed, are provided in at least two portions (A) and (C) whose surfaces of connection and assembly are in diametral planes or radial planes.

6. Method of manufacture in claim 5, characterised in that the helical conductor (2) and the body (1) are provided in several segments whose planes of connection and assembly pass through the axis of the coil, in that the ends for connection and assembly (2^2) of each turn element of the solenoid (2) are then provided with connection means enabling electrical conduction after connection of the portions (A) and (C) of the coil.

7. A coil as claimed in any one of claims 5 and 6, characterised in that the electrical connection of each turn element (2^1)) in order to reconstitute the complete solenoid (2) is carried out by means of male and female plugs which may be fastened together and are known as "banana plugs" having two or more radial contacts.

8. A coil as claimed in any one of claims 5 and 6, characterised in that the electrical connection of each turn element (2^1) in order to reconstitute the complete solenoid (2) is carried out by a complementary system of blades (5) and grippers (6) or other equivalent means acting by clamping or expansion.

9. A coil as claimed in any one of claims 5 and 6, characterised in that the electrical connection of each turn element (2^1) in order to reconstitute the complete solenoid (2) is carried out by immersion of one of its ends (2^3) in a fluid (7) which is a good conductor of electricity, connected electrically to the corresponding end (2^4) of the following turn element, the fluid (7) being contained in a cavity (1^1) of the body (1) which is leak-tight by means of a disphragm (8) shaped and ar-

ranged to be readily deformable during connection of each turn of the solenoid (2).

10. A coil as claimed in claim 9, characterised in that in the case of a fluid (7) having a sufficient surface tension, an assembly of brushes (b) acting as an obstacle to the fluid is used as a means for sealing the fluid, whilst the brush assembly allows passage to the end of the turn which is inserted therein.

11. A coil as claimed in claim 4, characterised in that the body, of cylindrical or other shape adapted to the component to be formed is provided in at least two portions whose surfaces of connection and assembly are in diametral or radial planes, the said portions of the body having a helical cavity or like hollow recess designed to be provided with the conductor element.

12. A method of manufacture as claimed in claim 11, characterised in that the body is formed in several segments whose planes of connection and assembly pass through the axis of the coil, in that a cavity or hollow recess is formed in the body having several segments and in that the cavity or recess is provided with a conductor element.

13. A coil as claimed in any one of claims 4, 11 and 12, characerised in that the body (9) is separated diametrally in order to form two shells (9^1 and 9^2) arranged at (9^3) so as to be articulated with respect to one another and constituting a clamp, and in that a recess (9^4) is formed in each of the shells to constitute a helical cavity designed to receive the conductor element.

14. A coil as claimed in claim 13, characterised in that in the case in which the conductor element belongs to the solid state, the latter is a copper wire (10) or another conductor material, carefully annealed, or a flexible braid of conductor metal.

15. A method of manufacture as claimed in claim 14, characterised in that the wire (10) (or the braid) is inserted in the helical cavity and is housed therein as a result of its flexibility until its two ends (10^1 and 10^2) emerge from the cavity (9^4) in order to be gripped and connected to a pulse generator for example.

16. A method as claimed in any one of claims 14 and 15, characterised in that the flexible conductor element (10) is introduced into the cavity (9^4) by mechanical means.

17. A method of manufacture as claimed in any one of claims 1, 11 and 12, characterised in that a tubular coil (11) is provided and is cut in one several radial or diametral planes, in that an insulating material is then caused to flow about the cut portions of the coil (11) in order thus to constitute two (or more) shell elements (12^1) and (12^2) designed to form an open body (12), in that once the shells are assembled (12^1 and 12^2) the turn elements formed in this way are connected together in a leak-tight manner in order to constitute a helical cavity (12^3) which is leak-tight and which serves to contain a fluid (13) which conducts electricity.

18. Method and means for introducing and withdrawing fluid from the solenoid constituted by the hollow turns (11^1) and connected at (14) and (15) to taps (16) and (17) as claimed in claim 17, characterised in that after closure of the body (12) and with the tap (16) closed, the air contained in the turns (11^1) of the coil is suctioned through an orifice (18) and the tap (17) open, in that when a sufficient vacuum has been created to attract the fluid (13) the tap (17) is closed and the tap (16) is opened in order to draw the fluid (13) contained in a tank (r) into the hollow turns (11^1), the fluid coming into contact with the connection terminal (14), in that the tap (16) is then closed and the coil may then be connected to a a pulse generator, in that after the electrical pulse required has been supplied pressurization is carried out through the orifice (18) and the taps (16) and (17) are opened in order to direct the fluid (13) into the tank (r), in that when the fluid has passed through the tap (16) it is closed and the shells (12^1 and 12^2) of the body are separated.

19. A coil as claimed in any one of claims 4, 11 and 12, characterised in that the dismountable body (20) is composed of at least two internal shell elements (20^1 and 20^2) and at least two external shell elements (20^3 and 20^4) between which there is engaged a solid conductor element acting as a solenoid (19), in that a radial play is also provided between the internal (20^1–20^2) and external (20^3–20^4) shells in order to pre-stress the turns of the conductor element (19).

20. A coil as claimed in claim 19, characterised in that the conductor (19) is wound in a helical groove (20^5) formed either on the external periphery of the internal shells (20^1–20^2) or on the internal periphery of the external shells (20^3–20^4) or distributed jointly over the shells (20^1–20^2) and (20^3–20^4).

21. Method of manufacture as claimed in any one of claims 19 and 20, characterised in that after assembly of the internal shell elements (20^1 and 20^2) and the closure of the external shell elements (20^3 and 20^4), the conductor element (19) is partially positioned in the helical groove (20^5) and in that the assembly is then introduced into the external shell (20^3–20^4) by a combined axial thrust and screwing movement.

22. A coil as claimed in any one of claims 4, 11 and 12, characterised in that the dismountable body is composed of a shell (21) which is cut diametrally in order to form two symmetrical portions (21^1 and 21^2) having an external helical groove (21^3) which constitutes, in combination with an insulating sheet (22) wound about the shell (21), a helical cavity designed to receive the solid conductor

element (23).

23. A coil as claimed in Claim 4, characterised in that the body (24) is made of a matter or material which may be elastically deformed, the conductor element being a copper wire (25) or other conductor material mounted helically in or on the said body (24).

24. A coil as claimed in claim 4, characterised in that its cooling may be carried out by the circulation of a fluid in the conduct or which is tubular or parallel to the latter.

25. A magnetic coil assembly substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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